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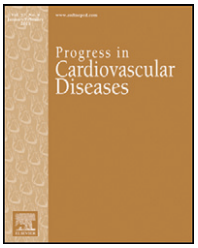

Robotic CABG and Hybrid Approaches: The Current Landscape

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ABSTRACT

Modern treatment of coronary artery disease (CAD) requires a patient-centered approach. With several technological advances, the options for treatment must be carefully weighed and novel approaches tested for safety and efficacy. In this chapter, we outline some of the new approaches available to cardiac surgeons for the treatment of CAD, including off pump coronary artery bypass grafting, minimally invasive as well as hybrid and robotic coronary revascularization. We discuss current evidence and controversies, and highlight the future directions and challenges in the field of surgical coronary revascularization.

Coronary artery disease (CAD) remains the leading cause of death in the United States (US). It is a disease of the elderly, with over 80% of all CAD deaths occurring in patients over age 65.[1] This is of significance because the proportion of Americans over age 65 is expected to double in the next decade and prevalence of important risk factors for CAD, such as obesity and diabetes mellitus is steeply rising.[2]

Myocardial revascularization is an effective treatment strategy shown to prolong survival. The two major therapeutic modalities for revascularization are percutaneous coronary intervention (PCI) and coronary artery bypass graft surgery (CABG). From the first aorto-coronary grafting operation using a saphenous vein conduit performed by Sabiston in 1962,[3] CABG quickly evolved as the "gold standard" for patients with multivessel CAD.

Standard CABG is performed under cardiopulmonary bypass (CPB) and is a low risk procedure but with potential for many morbid complications. These include the pain and mobility limitation due to a median sternotomy, deep sternal wound infections, acute renal failure, and strokes from aortic cannulation/clamping. Furthermore, there is an innate morbidity associated with the extracorporeal CPB circuit; such as the activation of complement cascades, the release of proinflammatory cytokines, and upregulation of inflammatory mediators that may affect postoperative morbidity.[4]

At its height, the popularity of surgical coronary revascularization spurred the development and improvement of catheter-based technology – first for imaging quality, and later for therapy.[5] The subsequent and rapid technological advancement of percutaneous techniques lead to wide adoption of PCI as a modality of myocardial revascularization.

Today, the optimal revascularization strategy (PCI vs CABG) for multi-vessel CAD remains controversial, and depends on the anatomic complexity of the lesions.[6,7] There is extensive evidence documenting the benefits and limitations or each modality. On-pump CABG remains the gold standard surgical treatment for multivessel revascularization, particularly for diabetic patients and those with left main disease.[6,8] Maximal survival benefits of CABG are conferred by the left internal mammary artery (LIMA) to the left anterior descending artery (LAD) grafts,[9–12] with 10-year patency rates of 95–98%.[10,11,13] On the other hand, saphenous vein grafts

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Abbreviations and Acronyms

AHTECAB = arrested heart totally endoscopic coronary artery bypass

BHTECAB = beating heart totally endoscopic coronary artery bypass

CAD = coronary artery disease

CABG = coronary artery bypass graft

CPB = cardiopulmonary bypass

DAPT = dual anti-platelet therapy

DES = drug-eluting stent

EndoACAB = endoscopic atraumatic coronary artery bypass

HCR = hybrid coronary revascularization

LAD = left anterior descending artery

LIMA = left internal mammary artery

MIDCAB = minimally invasive direct coronary artery bypass

OPCAB = off pump coronary artery bypass

PCI = percutaneous coronary intervention

RCT = randomized controlled trial

SVG = saphenous vein graft

TECAB = totally endoscopic coronary artery bypass

TEE = transesophageal echocardiogram

US = United States

(SVG) to non-LAD patency rates are moderate at best, with 1- and 15-year failure rates of 20 and 70%, respectively.[8,14,15]

Currently, PCI with drug eluting stents (DES) is appealing for being less invasive, leading to shorter hospital length of stay. The main drawback of PCI even in the DES era remains the high rates of reintervention.[15] With the rapid advancement of percutaneous technology, PCI continues to challenge the status quo of CABG for revascularization.[16,17] Current restenosis and in-stent thrombosis rates of DES are lower than the reported failure rates of SVG's, making PCI with DES a superior modality to SVG for revascularization of non-LAD lesions.[15,16] Nonetheless, even with DES, the LIMA to LAD graft of CABG continues to offer unrivaled safety and efficacy.[15,16,18]

Hybrid Coronary Revascularization (HCR)

The integration of traditional surgical approaches with PCI, or HCR, began in order to maximize the therapeutic advantage of each modality while minimizing the shortcomings. It was first introduced by Angelini et al in 1996 and is based on the rationale that the LIMA-to-LAD graft is superior to coronary stenting and that DES PCI are superior to SVG bypass to non-LAD lesions.[15,19]

Hybrid approaches that minimize use of CPB provide advantages for the elderly or patients with severe comorbidities. Of paramount importance to the success of HCR is a truly dedicated "heart team" consisting of cardiologist, interventional cardiologist, and cardiac surgeons working together to offer the best treatment option for each patient. It calls for a patient-centered approach rather than a specialty focused one. If treatment is focused by specialty, it is possible that the traditional separation of percutaneous techniques applied by cardiologist and surgical interventions by cardiac surgeons may preclude the benefits of treatment synergy. Though 'hybrid' approaches have been employed for years with the combination of PCI and CABG, the coordination of a planned, stepwise or concomitant use of these modalities has grown with the recent development of hybrid operating rooms (Fig 1).

Surgical technique

In the majority of HCR approaches, the LIMA-LAD anastomosis is performed using a minimally invasive approach, which aims to ameliorate three sources of morbidity: full sternotomy, aortic clamping and cardiopulmonary bypass. These techniques include off pump coronary artery bypass (OPCAB), minimally invasive direct coronary artery bypass (MIDCAB), endoscopic atraumatic coronary artery bypass (EndoACAB) and totally endoscopic coronary artery bypass (TECAB).[20]

OPCAB

In OPCAB, CABG is performed without CPB on non-arrested myocardium ("beating heart"). The primary challenge during OPCAB is balancing patient hemodynamics with optimal cardiac positioning. While CBP allows myocardial decompression and elective cardiac arrest for maximal coronary exposure without compromising systemic perfusion, manipulating the beating heart during OPCAB distorts venous return and may prohibitively decrease cardiac output. Several heart positioning devices have been designed to facilitate a reliable exposure, including devices to stabilize the myocardium around the target vessel. Target vessels must be isolated and blood flow controlled to allow sufficient visualization for sewing. Intracoronary shunts are used to circumvent the transient occlusion of the coronary allowing distal coronary perfusion. Though controversies remain regarding the superiority and learning curves the safety and efficacy of OPCAB are well established.[21,22] The principles of OPCAB are the foundation upon which all minimally invasive, hybrid and robotic coronary revascularization done today are built.

MIDCAB

In MIDCAB, a small (4–5 cm) anterolateral left-sided thoracotomy via the 4th/5th interspace is used to perform the anastomosis on a beating heart (off-pump). Specialized chest wall retractors and disarticulation or removal of costal cartilage are used to harvest the LIMA under direct vision. The small incision and avoidance of both sternotomy and CPB make MIDCAB appealing. However, its disadvantages include the increased technical difficulty of doing an anastomosis on a beating heart via a very small incision and the severe post operative pain experienced by patients.[23]